AN INDUSTRIAL APPLICATION: IMPROVING PERFORMANCE OF AN OLD FORGING PRESS

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DOI: 10.17973/MMSJ.2022_10_2022072

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Forging is one of the most important production methods in applications where the disadvantages of machining are not desired. However, the possibility of micro-cracking in the material at the end of the forging process should be considered. The main constraints here are the aging of hydraulic systems and possible casting defects. Therefore, in this study, the modernized process of an old forging press with a capacity of 30000 kN was carried out. For this purpose, the capacity of the forging press has been increased by modifying a new generation pump and hydraulic accumulator group. Thus, by increasing the cycle time of the hydraulic forging press, it is known that effective forging can be performed in a shorter time (from 1.7 to 1.3 seconds). When the modernization results are examined, it is seen that the necessary forging processes can be completed before the material cools down to the critical temperature.

KEYWORDS

open die forging, hydraulic forging press, fast forging, energy recovery

1. INTRODUCTION

Hydraulic presses are widely used in metal forming due to their simple construction, easy handling, and ability to transmit a large force [Li et al. 2017]. As a general classification, there are two types of hydraulic presses as open die [Schönfeld et al. 2001] and closed die [Altan and Henning 1969]. Hot or cold processing can be done in these presses [Doege et al. 2000; Altan et al. 2005]. On the other hand, standard hydraulic press movements can be classified as Free Falling, Braking (reducing speed after fast freefall), Compression (Crushing), Controlled pressure release, and Upstarts (fast starting and braking) according to the motion steps, respectively [Bhaduri 2018]. Control of transitions between movements is important in terms of shock loads that may occur in the machine, machine equipment life, and product quality. As in the defense industry, machinery, and automotive industries, it is desired to increase the mechanical properties of the materials shaped by forging. Contrary to many manufacturing methods, increasing the mechanical properties of the material in the forming process makes forging technology indispensable.

However, due to the rapid development of hydraulic-pneumatic technologies and the high costs of production of the presses used in the industry, these presses need to be updated. The most important problem here is not only the aging of the hydraulic system but also the lack of spare parts for the equipment used and the frequent stoppage of production accordingly. It is also very important to obtain the desired microstructure [Gao et al. 2000; Arentoft et al. 1997; Nye et al. 2001] at the end of the forging process and to eliminate possible casting defects in the material [Franzke et al. 2008; Ma et al. 2010]. Therefore, modernizing such presses is important for less cost and sustainable production [Unver et al. 2019]. Here, it is possible to modernize and increase productivity in three ways using known traditional approaches [Dindorf et al., 2020]. However, it is possible to modernize with the use of new generation control mechanisms as an alternative to these methods [Yao et al. 2016; Kaszuba et al. 2020].

In this study, a 30000 kN capacity hydraulic open die hot forging press was modernized with the project realized by HIPAS Design Center (HDC). In this context, a hydraulic forging press has been modernized to increase its cycle time and accordingly improve its performance.

2. MATERIALS AND METHODS

In a 30000 kN hydraulic forging press, the cycle time was 50 1/min for a 2 mm crushing dept and 20 mm return stroke, while it is desired to be increased up to 80 1/min for the same stroke. Press speeds were determined according to the cycle times. In this determination, the fast approach speed should be 250 mm/sec and the fast upward speed should be 250 mm/sec. With these values, pressing speeds should be a minimum of 150 mm/sec for 10000 kN, 120 mm/sec for 2000 kN, and 80 mm/sec for 30000 kN. It should be 100 mm forging with 30000 kN force, and 15 1/min strokes at 200 mm take-off distance. The fast forging stroke should not exceed 30 mm [Ma et al., 2010]. In the forging process, the crushing depth is made in three force stages Therefore, it is aimed to increase efficiency in the hydraulic system. Achieving these values was accomplished in three stages. In the first stage, the appropriate pump selection was made. The Rexroth A4VBO 450HS5 series pump [Rexroth, 2018 a] was chosen for high response dynamics and accuracy flow characteristics. In the second stage, hydraulic counterweight accumulator groups were determined for fast take-off. A total of eight batteries with a volume of 55 liters each were selected, as shown in Figure 1. Rexroth "2WRCE 40-4X" [Rexroth, 2021] series proportional valve size 40 with high response dynamic is used in order to prevent the speed profiles and shock impulses that may occur in the system. The hydraulic diagram created in line with these choices is shown schematically in Figure 1. Solenoid Valve (SV), Proportional Valve (PV), Check Valve (CV), Pressure Relief Valve (PRV), Pilot Accumulator (PA), abbreviations are used to express the operation of the process carried out on this diagram. There are 3 cylinders with a force of 10000 kN on the press. During forging, it is required that the forging press apply 10000 kN, 20000 kN, and 30000 kN of force to the material, depending on the material type. The hydraulic press stands at the top with the SV4 and SV5 valves. Activation of the SV4, SV5, and PV1 valves starts the downward movement of the press. The lower speed of the press is controlled by the PV1 proportional valve. Valves SV1, SV2, and SV3 are activated when the press is getting close to the material. According to the desired force, 10000 kN of force is obtained when the SV3 is activated, and 20000 kN of force is obtained when the SV2 valve is activated. For 30000 kN of force, the SV2 and SV3 valves must be activated at the same time. Here, it is important to underlined that SV3 used for fast pressure discharge. After the rough forging process, the SV7 is activated so that the press can switch to the rounding function, and the main accumulators are filled with oil at the desired pressure with the auxiliary pump. Oil pressure is controlled by Transmitter on the line. The compressed oil flow in the press lifting line is controlled by the PV2 proportional valve. With this oil controlled, the upward speed of the press can be adjusted with counter cushion accumulators. In addition, PRV safety valves are used for the safety of the system.

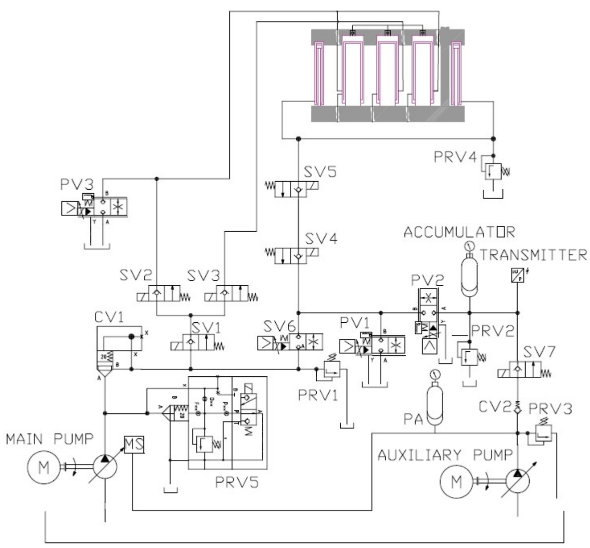

Fig.1. The Hydraulic Unit Diagram

The forging parameters, which consist of 10000 kN, 20000 kN, and 30000 kN in three different stages during forging with the valves used, are shown in Table 1.

Table 1. Forging Parameters Formed According to the Force Levels of the Press

Press Force Levels (kN)	Crushing Depth (mm)	Return Stroke (mm)	Number of Strokes Minimum (1/min)
30000	*100*	*200*	*15*
20000	*100*	*200*	*20*
20000	*50*	*100*	*35*
10000	*50*	*100*	*50*
10000	*5*	*25*	*70*
10000	*2*	*20*	*80*

The operating logic of the selected A4VBO 450HS5 pump is shown in Figure 2.

(a) (b)

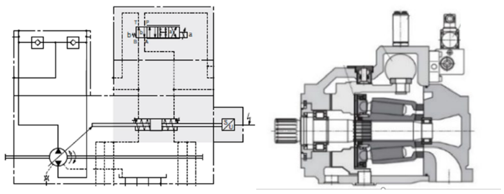

Fig. 2. Main Pump Hydraulic Diagram (a), Main Pump Sectional View (b) [Rexroth 2018a; Rexroth 2018b]

The proportional valve shown in Figure 3 was chosen because of its high response dynamic.

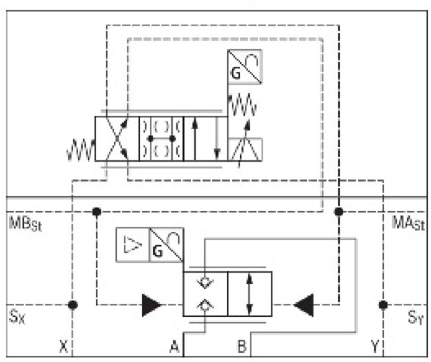

Fig.3. Proportional Directional Valve Hydraulic Diagram [Rexroth 2021]

Size 40 proportional valve [Rexroth 2021] has been chosen reason of flow performance. The reaction time of this valve is 25 ms for open command and 20 ms for close command under full scale conditions.

Lifting cylinders area of the press and the desired working stroke are important in accumulator calculations. The amount of oil to be compressed in each stroke movement is calculated using equation 1 based on the total accumulator volume and nitrogen gas pressure.

$$V_0 = \frac{\Delta V}{\left(\frac{P_0}{P_2}\right)^{\frac{1}{n}} \cdot \left[\left(\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}}\right)-1\right]} \quad (1)$$

Apart from these, a hydraulic infrastructure that is resistant to high speeds and impacts has been established.

3. RESULTS AND DISCUSSION

The material in the form of an ingot taken from the annealing furnace during the forging process is first subjected to the rough shaping cycle according to the type and dimensions of the part to be manufactured. In the stage called rough forging, the need for high pressure is required as deep crushing will be made on the press forging material. At this stage, it is important to increase and discharge the pressure on the actuators in a controlled manner and to minimize possible impacts with high-speed pressing. The forming steps are shown in Figure 4. First, the press makes rough shaping to the ingot material. The reason for high deformation on the material micro-cracks may occur during initial rough shaping.

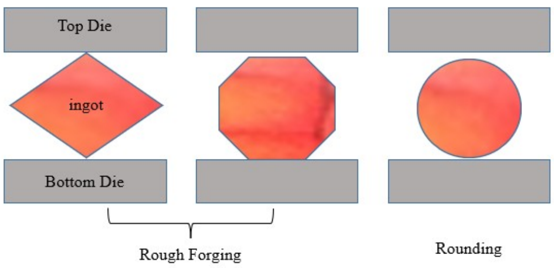

Fig. 4. Rough Forging and Rounding

After rough forging, especially during the forging of round parts, the press must apply hundreds of strokes on the rotating material. This way rounding can be done better. Therefore, cycle time and position precision are important.

The parts to be forged are heated homogeneously in the annealing furnace at a temperature of 1000 °C and above, depending on the material type. In this way, the material can be shaped much more easily. However, with the start of the forging process, the part starts to cool down. During the forging process, the temperature drops below a certain value increase the risk of micro-cracks in the part. The risk of microcracks creates the possibility of material scrapping. Due to these reasons, time, material, and labor losses occur. To minimize these risks, there is a need to reheat parts that have started to cool. It should be ensured that the press completes the forging process quickly before the material cooling reaches critical levels. Values considered on the basis of efficiency in the forging press should be set as 50 1/min for 20 mm stroke and 80 1/min for the same stroke. When the targeted values are reached, waste of parts is prevented and the manufacturing process is shortened at the same time.

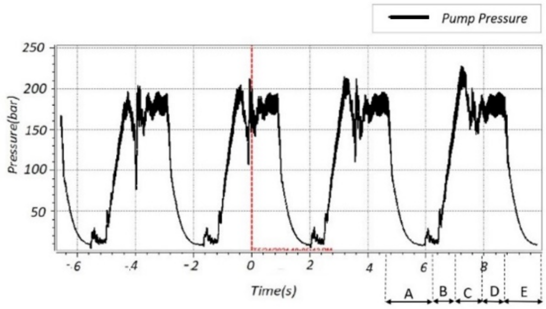

Fig.5. Measured Pump Pressures during Crushing

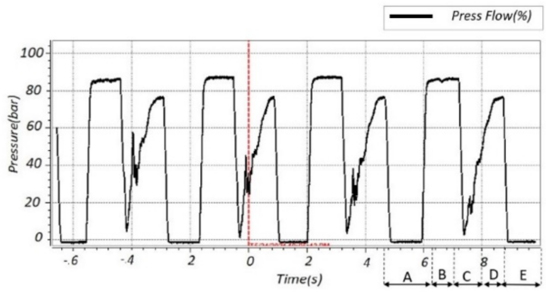

Fig.6. Measured Pump Pressures Rates during Crushing

The measurement data was prepared using the IndraWorks commercial Engineering software. The pump measurement graph taken from the press is in Figure 5 and Figure 6. In zone A, the press is waiting above. In the B zone, the press moves down at first. Performs the crushing process in the C zone. Here it is seen that the crushing has risen above 200 bar level. It is in decomposition in zone D. In zone E, the press goes up.

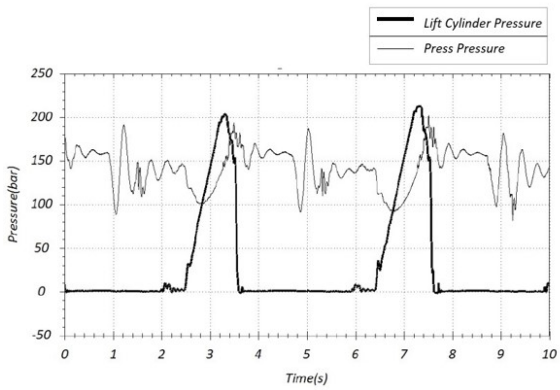

Fig. 7. Measured Lift Cylinder Pressures during Crushing

The graph shows the cycle of the press in Figure 7. Since we increase the crushing flow rates and pressure, the real advantage was gained in crushing.

The graph showing the fast discharge and fast response times is in Figure 8. The measurement data was prepared using the HYDROcom6 software. Reduced the time from 0.25 seconds to 0.15 seconds in rapid discharge. In this way, the number of hits, which was 60 when considered on a time basis, was reduced to 30-35 hits. Also, the fast operation of the press is ensured. Therefore, the forging process, which took 1 hour and 10 minutes, was reduced to 40-45 minutes.

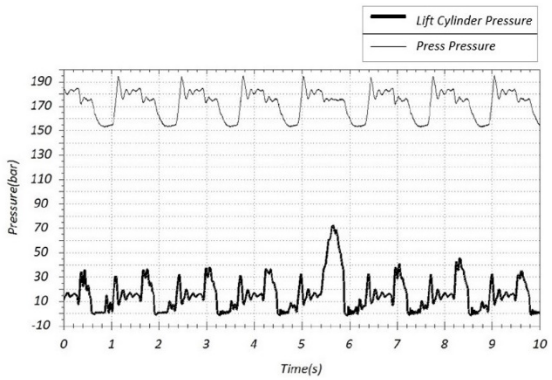

Fig. 8. Measured Pressures during Rounding

Half of this time is crushing and half is rolling time. In other words, the crushing process that was previously done in 30-35 minutes has been reduced to 20-25 minutes. Crushing which used to take 2 seconds in the old system of the press is reduced to 1.5 seconds.

4. CONCLUSION

In this study, the hydraulic infrastructure of the 30000 kN open dies hot hydraulic forging press was calculated, prepared, and analyzed.

In summary, the desired values have been reached. 18 strokes per minute were achieved in 100 mm 30000 kN crushing. A rapid approach speed of 400 mm/s has been achieved, reducing the cycle time. As a result, values above the targets were achieved with the obtained data. However, the cycle time was reduced because the operator could not keep up with the cycle time at this speed. Therefore, the cycle time has been reduced from approximately 1.7 seconds to 1.3 seconds.

With these results, the efficiency of the hydraulic press has increased to 30 %.

NOMENCLATURE

V_0 = accumulator gas capacity (liters)
P1 = operating pressure by free flow (absolute bar)
P2 = P + ΔP = max allowable pressure (absolute bar)
n = 1.4 adiabatic coefficient (quick discharge phase)
Q = flow rate in the piping (m^3/h)
ΔP = Allowable overpressure (bar)

ACKNOWLEDGMENTS

This work was carried out by HIPAS Hydraulics and Pneumatics Co.-Design Center within the scope of project number 46.

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